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THE SYSTEM OF THE STARS.

The System of the Stars. By Agnes M. Clerke. (London: Longmans, Green, and Co., 1890.)

THE gifted author of this work became justly famous by the publication of her now classical "History of Astronomy during the Nineteenth Century." The mass of accurate information there brought together, and the delightful way in which it was related, won well-earned praise on every hand. Her success in that effort has now encouraged her to a more ambitious one. In addition to the simple relation of facts, she ventures to give her opinions on the various inferences which have been drawn from them by those who have spent many years in elaborate investigations. Still, "the statement of facts has been kept primarily in view, but the more important efforts to interpret them have been noticed, and the difficulties attending rival theories impartially pointed out."

We may look upon the book as consisting of two parts, one simply presenting a most valuable mass of information, while the other gives the author's views on contemporary work. As far as the first part is concerned, Miss Clerke has done her work admirably. We regret, however, for her own sake, that she has not confined herself entirely to this kind of work. A trustworthy book, bringing together all the latest discoveries and views of competent judges as to their true meaning would have been priceless, and no one has better opportunities for such an undertaking than Miss Clerke. As it is, we find a certain amount of information, selected rather than complete, intermingled with her own views. Certain facts have been omitted, not with the intention of misleading, but because their importance was apparently not recognized.

The first two chapters give general ideas of the problems of sidereal astronomy, and the methods of research which are adopted. The third chapter deals with "Sirian and Solar Stars," and here we get the first glimmerings of the author's special leaning to what may be called the "electrical theory." There is little difficulty connected with these groups of stars: it is generally agreed that the Sirian are the hottest, and that they have a definite evolutionary connection with the solar ones. Like Vogel, the author includes amongst the Sirian stars those stars of Orion (*e.g.* Rigel) which are characterized by very few visual and comparatively few photographic lines. Although their spectra show hydrogen absorption conspicuously, they differ very widely from the Sirian stars in other particulars. Their structure is not improbably of a very different character, due no doubt to their connection with the great nebula. Condensations taking place away from such a widely-diffused nebulosity probably follow a different path, and for the present the Orion stars should be classed apart from the more perfectly formed ones of the Sirian type. *a* Cygni, again, is included amongst the "solar stars," although its spectrum exhibits very wide divergences from that of the sun; the characteristic structure about the G region is entirely absent, while there are many well-marked non-solar lines in its spectrum. Altair, also, is said to be located between the Sirian and solar stars; but here again there

is little resemblance to either, beyond the lines of hydrogen; the diagram on p. 43 makes this sufficiently evident. The more the "solar stars" are studied, the more it seems probable, as Mr. Lockyer has pointed out, that they must be divided into two groups—one of increasing temperature, including such stars as Aldebaran, *a* Cygni, and Altair; the other of decreasing temperature, including such stars as Procyon, Capella, Arcturus, and the sun.

The author advocates that the difference between the Sirian and solar stars can be accounted for by assuming the solar stars to be the more strongly electrified. It is argued that an increase of temperature in such a star as the sun would increase rather than diminish the complexity of its spectrum, by increasing the absorbing metallic vapours. It is not evident, however, how a diminution of the electrical repulsion would cause such an increase of the hydrogen absorption as that indicated in the spectra of the Sirian stars, the author simply asserting that the layers of hydrogen would be much more concentrated than at present. The increased thickness of the hydrogen lines is more probably due to some cause which increases the quantity of hydrogen in the atmospheres, and for the present, at all events, that may be regarded as the dissociation of the metallic vapours due to the increased temperature brought about by condensation.

Chapter iv. deals with the stars having banded spectra. These, it is well known, are of two types—one showing dark flutings most probably of metallic vapours, and the other dark flutings of carbon. They form Secchi's third and fourth types respectively. Flutings undoubtedly indicate that the vapours producing them are at a comparatively low temperature, and the presumption would be that the red stars are cooler than the yellow and white ones. On this point it is remarked that "the alteration obviously implies an augmented extent of absorbing atmosphere. For the bands must originate in a region of less heat—that is, at a greater distance from the stellar photospheres than the lines."

Let us consider first of all the stars of the third type, in which the hottest members show a fluted spectrum superposed upon a line spectrum, whilst there are practically no indications of the hydrogen lines. It has been suggested on various grounds that the stars of this type are not stars in the true sense of the word, but that they are of a cometary nature; that is, that they are composed of discrete masses, and not of a photosphere surrounded by glowing vapours. Perhaps the chief evidence in favour of this view lies in the alleged existence, in the spectra of these stars, of the bright carbon flutings which characterize the spectra of comets. The author does not consider the evidence on this point conclusive, but this appears to be partly due to the fact that all the evidence has not been brought together. In Nova Orionis, with a well-marked spectrum of this type, Dr. Copeland demonstrated the presence of two of the cometary flutings with almost absolute certainty (*Monthly Notices R.A.S.*, vol. xvi. p. 110); Messrs. Lockyer and Fowler showed them to be present in *a* Herculis and Mira Ceti (*Proc. Roy. Soc.*, vol. xlvii. p. 35); and, more recently, Mr. Maunder has stated that in the spectrum of a Herculis the brightest green fluting is coincident in

position with the chief hydrocarbon band, and, moreover, presents exactly the same appearance ("Greenwich Spectroscopic Observations," 1888, p. 13). The brightening of this same fluting at the maximum of Mira tends to the same conclusion. Not a single one of these important observations, however, is referred to by Miss Clerke, although, if they are confirmed by future work, they must inevitably revolutionize the old idea that the red stars of the third type are "suns." The objection that the dark band adjacent to this, if an effect of contrast, would indicate that in the stars where it appears very dark there was no continuous spectrum at all does not hold good. A sun-spot appears intensely dark by contrast with the surrounding photosphere, and yet we know that it is brighter than the electric light. It is further objected that the other two cometary bands do not present themselves; but the blue band was included in both Copeland's and Fowler's observations, and it must be remembered that the citron band is the faintest in comets, and that in the stars in question it may be masked by the dark flutings which fall near it. It is stated (p. 56) that "there are grave objections to admitting the reality of the masking," but, as these are not formulated, it is impossible to discuss them. Whether the masking be admitted or not, the third band seen in comets often assumes the positions of two of the apparent bright bands in the spectra of stars of the third type, and with the additional evidence of the other two flutings, it is only reasonable to suppose that comets and these stars are bound together by close ties of relationship. Hence we cannot agree that "conclusive evidence seems to be provided that stellar spectra of the third type originate at various heat-levels in powerfully ignited vaporous envelopes." The mere existence of a continuous spectrum cannot be regarded as evidence of the existence of a photosphere. Comets, as a rule, give continuous spectra in addition to their fluted radiation, but few would venture to assert that this is produced by the radiation of a photosphere. The case of Mira at maximum, when the hydrogen lines appear bright, is quoted as evidence of an intensely high temperature close to the supposed photosphere; but this, it should be added, is abnormal, and only occurs when, through some cause or other, the star is some hundreds of times its normal brightness.

In support of the view that the various phenomena presented by stars of this type are produced by a photosphere underlying a highly distended atmosphere, the observations of the intermittently hazy aspect of some of them is referred to. It is only necessary to add here a remark omitted by the author—namely, that this equally supports the "cometary theory" of their structure, and is, in fact, one of its essential points. The electrical theory is again brought to the front in connection with these stars, it being suggested (p. 61) that the red stars are more strongly excited than the Sirian and solar stars, and that, in consequence, the atmospheres are very widely distended.

Coming now to the other type of red stars, in which we get the cometary spectrum reversed, Miss Clerke is again in error. It has hitherto been pretty generally accepted that these stars are almost on the verge of extinction, but our author says that "their powerful incandescence is undoubted" (p. 64). The evidence of

such a temperature depends upon very doubtful facts. In addition to the chief bands of carbon, the spectra exhibit six secondary bands, two of which agree almost in position with the D lines of sodium and the E line of iron, and on the strength of this it is stated that, "through the obscurity of the carbon bands can be distinctly seen a 'Fraunhofer spectrum'—a spectrum, that is to say, composed, like that of the sun, of dark metallic lines thrown out upon a continuous background. Among the substances originating in them, sodium is certainly, iron probably, recognizable." If the existence of the Fraunhofer lines be admitted, there should be no hesitation in connecting these stars with the solar stars, for a slight but certain carbon absorption is exhibited by the sun, and there would be no need for the subsequent remark (p. 89) that "their spectroscopic isolation leaves us without the means of tracing their relationships." It is more likely that the secondary bands are identical with those in the solar spectrum which are produced by the absorption of our own atmosphere (see Proc. Roy. Soc., vol. xlv. p. 92), and the approach to a planetary condition is thus plainly foreshadowed. This piece of important evidence is not referred to by Miss Clerke, notwithstanding its suggestiveness.

"Gaseous Stars and Nebulæ" form the subject of chapter v., the idea being to continue the succession from Sirian and solar stars, through the red stars and bright-line stars to nebulæ. If the stars of the fourth type and those like Rigel be omitted, this may be taken as the probable sequence of events. The nebulæ are closely connected with the bright-line stars, these, again, with the stars of the third type—the bright hydrogen lines here showing similarity of constitution; stars of the third type merge insensibly into stars like Aldebaran and *a* Cygni, and, finally, into stars like Sirius.

So far so good; but the author is inconsistent. The Orion stars had previously been grouped with those of the first type, but on p. 72 we find it stated that "the brilliant stars of Orion may be said to mark the first stage on the road to nebulousity." We first find nebulæ placed at one end of the series and then at the other.

Opinions are still divided as to the interpretation of the spectra of "gaseous stars," but these bodies can certainly no longer be regarded as suns; they are similar in structure to the nebulæ, whatever that may be. There are some nebulæ which appear as little more than points of light, and we have Prof. Pickering's word that their photographic spectra strongly resemble those of the bright-line stars. Visually, their spectra are identical with those of such widely-diffused masses as the Great Nebula in Orion. A more perfect sequence of spectra from nebulæ to stars like Sirius could not be wished for.

"Sidereal Evolution" forms the subject of chapter vi. Nebulæ were formerly regarded as quite "distinct and of another order from the group of cosmical bodies to which our sun and the fixed stars belong"; but now we can agree with Miss Clerke in accepting the view that they gradually "merge into unmistakable suns" (p. 84).

"But when we come to the various classes of stars, the order of their succession is less easily determined. The earliest and most obvious idea on the subject was based on a false analogy between the colours of the stars and the colours of glowing terrestrial solids. Red stars, it

was thought, should be regarded, because they had cooled from a condition of white heat, as older than white stars. The colours of stars, however, depend primarily upon the quality and extent of their absorbing atmospheres, and quite secondarily upon their stage of incandescence" (p. 85).

Surely the quality of the absorbing atmosphere must also depend upon the stage of incandescence, and colour may therefore still serve as a guide to the temperature and age of the stars. That the red stars of the third type are young may readily be granted from the evidence previously referred to; but, at the same time, it must be allowed that their temperature is comparatively low. It is, however, argued that the stars of the fourth type are also at an early stage of growth, but the evidence depending upon their alleged intermittently hazy aspect, indicating enormous atmospheres, is not conclusive on this point. In fact, the authorities quoted (Messrs. Pogson and Peek) have only observed it in *variable* stars of the *third* type. From the fact that there is carbon absorption in the sun, it seems reasonable to suppose that the fourth type stars are at a lower temperature than stars like the sun, and are probably the result of the cooling of such bodies.

The discussion of the sun's status amongst celestial bodies naturally comes here. That it was once a star like Betelgeuse, then like Aldebaran, is granted. But has it passed through the Sirian stage? This involves the question of whether the "solar stars" are divisible into two distinct groups, but our author is not quite clear upon this point. She remarks that "it is scarcely conceivable that a state abolished as an effect of condensation should be restored by its further progress" (p. 91). If there are two groups of "solar stars," one group will include bodies a little more condensed than the stars of the third type, in which perfect photospheres have not been formed, while the other will include bodies formed by the further condensation of such stars as Sirius. The two states would not be identical. We know that the sun has a photosphere, and hence the suggestion that it is a cooling body. Its relation to the stars of the fourth type strengthens the view that the sun has already passed through the Sirian stage and will eventually be a fourth type star. Miss Clerke, however, does not accept this view of the effects of further condensation upon a Sirian star, but suggests another which has not a single fact to support it. It is pointed out that the spectrum of the satellite of Sirius, if it could be observed, might give some clue to the spectrum of a waning body; and she is bold enough to predict that it will prove to be of "an undistinguished character, interrupted neither by bands nor conspicuous dark lines, and feeble, not through effects of absorption, but intrinsically. The same dull uniformity may be expected to belong to the spectra of all stars of impaired splendour" (p. 92). What, then, will be the transition stage, say between Sirius and such a body as that suggested? The broad hydrogen lines could not disappear suddenly, and we know that there are no stars showing fine hydrogen lines alone. In fact, it is especially emphasised (p. 42) that "the conspicuousness of rays due to absorption by ordinary metals in the spectra of white stars varies inversely with that of the hydrogen series." Some solar stars, at least, must there-

fore represent the stage that will be arrived at by the cooling of such a star as Sirius, and the evidence tends to show that the sun is one of them.

Further, if the spectrum of such a waning star were simply dimly continuous, the absence of an atmosphere would be indicated. We certainly know that the moon has no atmosphere, but it does not shine by light of its own. Even the earth has sufficient atmosphere to give a very definite spectrum of absorption, and this atmospheric absorption must have been much greater when the earth was hotter than at present. Cooling stars are not likely, therefore, to give such spectra as Miss Clerke supposes, for we know that a powerfully absorbing atmosphere remains after the photospheric luminosity has disappeared. The spectrum of such a cool atmosphere would no doubt be a fluted one.

Temporary and variable stars occupy the next two chapters, and some valuable information is brought together in an interesting way. Among the spectroscopic observations of new stars, probably the most important were those of Nova Cygni. The most striking thing here was the increased brilliancy of the chief nebula line as the star faded away. That is to say, as the star cooled, it became a nebula, thus affording very decided evidence that nebulae are comparatively cool. The dimming of new stars takes place so suddenly that it is certain only small bodies can be in question, and the suggestion has been made that new stars were produced by collisions of meteor-swarms. For collisions of this kind, Miss Clerke substitutes "grazing encounters with nebulous masses revolving in hyperbolic orbits, and overthrowing, by their proximity to the attractive body, a thermal equilibrium already eminently unstable." In the case of Nova Cygni no star had previously been recorded in its place, and it is difficult to conceive that such a grazing of a dark body, supposing one existed, with a moving nebulous mass could produce such a brief "conflagration" as was observed.

The old theories of stellar variation, assuming the existence of immense masses of slags in the photospheres, or that one side of a variable star was brighter than the other, have long been discarded. No single explanation is good for all variables, but there is no difficulty with those of the Algol type. After brief references to the explanations which have been suggested for the red stars, Miss Clerke concludes that "the time has not come to formulate a theory of stellar variability" (p. 125). The only comprehensive one we have as yet—the collision theory—is not considered sufficient by Miss Clerke; but careful consideration will remove the objections made against it. This theory assumes as proved the cometary character of stars of the third type, and suggests that the increase of light at the maximum of a variable of this kind is produced by the collisions at the periastron passage of satellite comets or swarms of meteorites. It is objected (p. 124) that this state of things could not long subsist, as the satellite swarm must inevitably become extended into a ring, with complete effacement of variability. This is certainly true, but we have only to look at the "November swarm" in our own system to understand that the disruption of the satellite comet need not be very speedy. This swarm has been observed now for at least a thousand years, and yet the brilliancy of the showers is apparently not diminished. Mira Ceti is the

only variable of this class which has been observed for a long period, and the observations in this case only extend over three hundred years. On p. 124 we read further:—

“The periodicity of variable stars is, besides, of far too disturbed a kind to be thus accounted for. Systematic stability would assuredly prove incompatible with the enormous irregularities it discloses. The abrupt acceleration or retardation, for example, by a month of the hypothetical attendant swarm of Mira, would be impossible without such a total change in the elements of its circulation as would unmistakably break the continuity of its returns. But there are other objects far more recalcitrant than Mira to this mode of explanation. Take the outbursts of U Geminorum. They are not wholly capricious. There is a certain disorderly order about them by which they are manifestly akin to the changes of the more strictly periodical stars. We cannot relegate them to a class apart and invent a fresh hypothesis to suit them; the collision theory, to be acceptable in the one case, must be capable of meeting the other. But we can scarcely conceive any construction of assumptions by which such an extension of its powers could be effected.”

Irregularities such as are here referred to are almost bound to occur if the collision theory be true. A star is not limited to one short-period comet any more than is our sun. There may very well be swarms of various masses travelling round the star in regular orbits, and occasionally a swarm travelling in an open orbit may enter the system. These swarms would so react upon each other and upon the central swarm that irregularities would be the inevitable result. Again, the central swarm might vary locally, like the Andromeda nebula, so that the revolving swarm would not always encounter it under exactly the same conditions. That the intervals between successive maxima and the magnitudes at maxima are not constant does not prove that the actions are not periodic.

In NATURE, vol. xlii. p. 550, there are some interesting examples of the apparently irregular results which might be produced by the integration of two sources of regular light variation. Two or more swarms of regular periods with the occasional advent of one moving in a parabolic or hyperbolic orbit, can be made to explain all the facts relating to this class of variables. In the variables of the fourth type, the same explanation holds good, if we consider the direct luminosity of the cometary swarms to be added to that of a dim condensed central body. Miss Clerke, however, supposes that variability depends upon extensive atmospheres, these being disturbed periodically in some way or other, probably by the tidal action of a satellite, so as to produce the observed fluctuations of light. It is a question whether such an atmospheric disturbance could increase the apparent brightness of a star hundreds of times.

The succeeding eight chapters are mainly descriptive, dealing with colour phenomena, double stars, stellar orbits, star clusters, and the forms of nebulae. It is only necessary to say of these that they are admirable.

Chapter xix., “The Nature and Changes of Nebulae,” discusses the relations of nebulae and comets, and nebular variability. Referring to comets and nebulae, it is stated (p. 286) that “traces of a spectroscopic analogy can indeed be shown to exist; but they are met with only in the secondary elements of each spectrum. The resemblance seems only incidental; the dissimilarity essential.”

It has, however, previously been pointed out (p. 76) that two faint comets observed by Dr. Huggins in 1866–67, gave spectra identical with that of a faint planetary nebula. This may well be regarded as conclusive spectroscopic evidence of the similarity between comets and nebulae, but although it is apparently only regarded as of secondary importance, “it does not detract from the closeness of a physical analogy.” It seems unphilosophical to rely on telescopic similarity when such conclusive spectroscopic evidence is at hand. We might go further than Miss Clerke, and say that as a comet is usually regarded as a swarm of meteorites the same view must be accepted for nebulae. The information relating to the views on the temperature of nebulae is very meagre. Some argue that they are intensely hot, whilst others argue that they are cool bodies not unlike comets. Apparently the only statement on this important subject is that on p. 77, where it is stated they “are not greatly heated.” Indeed, the evidence afforded by their cometary relationships and by Nova Cygni is conclusive. Yet, as late as 1889, Dr. Huggins stated his belief that the temperature of nebulae is very high.

It will thus be seen that, although a good deal of Mr. Lockyer's recent important work is left out of consideration, two of his main propositions are accepted by Miss Clerke; viz. (1) “nebulae merge into unmistakable suns,” and (2) they “are not greatly heated.”

The remaining chapters consider the distances of the stars, the motion of the solar system, proper motions, the Milky Way, the “status of the nebulae,” and finally the “construction of the heavens.” The two latter really discuss the distribution of stars and nebulae, and bring together a wonderful amount of information which has hitherto been much dispersed.

In justice to Miss Clerke, it is only fair to add that she has exercised a sound judgment on many problems, and has made many valuable suggestions as to the lines on which future investigations should be proceeded with.

The book is well illustrated throughout, among the illustrations being reproductions of some of Mr. Roberts's marvellous photographs. With the exception of that of the Andromeda nebula, these are highly satisfactory.

In conclusion, we would again express our unqualified admiration of a good deal that the book contains, but we cannot help feeling that its value as a contribution to astronomical literature would have been greater if the author had confined herself to simply giving a trustworthy account of contemporary astronomical researches, and of the views held by competent thinkers. A safe and impartial guide to current thought is still a desideratum.

F.

ACROSS GREENLAND.

The First Crossing of Greenland. By Fridtjof Nansen.

Translated from the Norwegian by Hubert M. Gepp. With Maps and numerous Illustrations. Two Vols. (London: Longmans, Green, and Co., 1890.)

THE only serious fault to be found with this book is that it is much too long. Only a small proportion of it is devoted to the actual crossing of Greenland, the rest being occupied with matters which might have been,